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Experimental investigation on behaviour of HFRC frames with infills against lateral cyclic loads

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ABSTRACT

Infilled frame construction represents a common type of construction in urban areas. The frames carry gravity loads and earthquake loads while the infills provide a building envelope and or internal partitioning. Masonry infills in reinforced concrete buildings cause several undesirable effects under seismic Loading. Hence seismic codes tend to discourage such constructions in high seismic regions. However, in several moderate earthquakes, such buildings have shown excellent performance even though many such buildings were not designed and detailed for earthquake forces. It is seen that the masonry infills contribute significant lateral stiffness, strength, overall ductility and energy dissipation capacity during moderate earthquakes. By providing fibres in the critical zones it is possible to improve the performance of the frames against lateral loading. Hence an attempt is made by using hybrid fibres in the frames in various proportions and to determine the behavior of the hybrid fiber reinforced concrete frames under lateral cyclic load. The fibers used here are polyolefin and steel fibers. The percentage of fibers used here are 1.5%, & 2%. This paper presents the experimental results of RC frames which compare the strengths of control frame and Fibre Reinforced Concrete (FRC) frames.

Key words: Masonry infill, RC frames, lateral cyclic load

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1. INTRODUCTION

1.1. Fibre Reinforced Concrete

Fibre Reinforced Concrete is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lends varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities (Subramanian, and Prakash Rao, 2003). The main reasons for adding steel fibres to concrete matrix is to improve the post-cracking response of the concrete i.e., to improve its energy absorption capacity and apparent ductile and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material. In filled frame construction represents a common type of construction in urban areas. The frames carry gravity loads and earthquake loads while the infills provide a building envelope and /or internal partitioning (Ichinose, 1991).

1.2. Steel fibers

The fibers used here are barchip steel fibres. These fibres are used to reduce shrinkage cracking. It increases the flexural strength, fracture toughness and impact resistance. The main aim of using steel fibers is to control cracking and to increase the concrete strength.

1.3. Polyolefin fiber

Polyolefin fibers are those fibers produced from polymers formed by chain growth polymerization of olefins (alkenes) and which contain greater than 85% polymerized ethylene, propylene, or other olefin units. The fibers are unaffected by solvents at room temperature and are swollen by aromatic and chlorinated hydrocarbons only at elevated temperatures. The hybrid fibers used here are 30% of pol olefin fiber and 70% of steel fiber.

1.4. Types of fibre

- Natural, vegetable or mineral fibres
- Alkali or non-alkali resistant glass fibres
- Polypropylene fibres
- Steel fibres

Table 1
Properties of Fibre

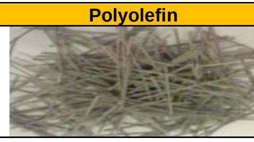
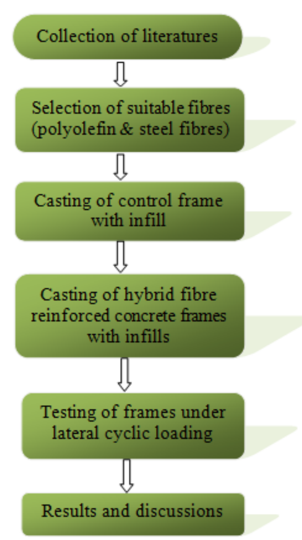
S.No	Fibre Properties	Polyolefin	Steel Fibre
1	Appearance		
2	Length (Mm)	48	30
3	Shape	Straight	Wavy
4	Size/Diameter (Mm)	0.7	0.6
5	Aspect Ratio	39.34	60
6	Density (Kgm^{-3})	920	7850
7	Young's Modulus	6GPa	210Gpa
8	Tensile Strength	550Mpa	532Mpa

Table 2
Properties of Cement, FA, CA

Property	Cement	FA	CA
Fineness	1%	4.72	8.21
Consistency	30%	-	-
Initial setting time	80 mins	-	-
Specific gravity	3.18	2.62	2.78

- Carbon fibres and other fibre types
- Polyolefin fibres
- Synthetic fibre (Acrylic, Aramid, Carbon, Nylon, Polyethylene, Polyolefin & Polypropylene).

Methodology of this project



2. PROPERTIES OF FIBRE
Properties of Fibres are shown in Table 1.

3. OBJECTIVE
- The main objective of this project is to determine experimental investigation on behavior of HFRC frames with infills against lateral cyclic loads.
- To compare the strengths of various specimens (cube, cylinder & prism) between control concrete and FRC (0.5%, 1%, 1.5% & 2%)
- The fibres such as polyolefin and steel fibres of varying percentage (1.5%& 2%) are used to determine the strength of concrete frame.

4. METHODOLOGY
The main aim of this project is control the cracks by using fibres and also to study the behaviour of HFRC frames with control concrete frames.

5. TESTS ON MATERIALS
The preliminary tests were conducted on cement, fine aggregate, coarse aggregate and the test results were obtained. Based on the results obtained the mix proportion for M_{25} concrete is done. The properties of materials tested are mentioned in table 2.

Mix Proportion for M_{25} Concrete

Cement = 425.73 kg/m^3
Fine aggregate = 649.498 kg/m^3
Coarse aggregate = 1174.42 kg/m^3
Water content = 191.58 kg/m^3
Water-cement ratio = 0.45
C: FA: CA = 1:1.52:2.75

The mix proportion for M_{25} concrete is calculated using IS 456:2000, IS 10262:2009.

6. TEST SPECIMENS
The compressive stress, split tensile strength and flexural strength of concrete are determined by casting cubes of size 150x150x150 mm, cylinders of size 300x150 mm and prisms of size 500mmx100mmx100mm and allowed for 28 days curing and the test results were obtained for various percentage of fibers (poly olefin and steel fibers).

6.1. Compressive Strength Test Results
The comparative results for compressive strength of concrete cube between control specimen and HFRC specimens are shown in the graph in Figure 1. The comparison of the 28 days cube compressive strength results shows an increase in compressive strength for percentage of fibres (0.75%, 1%, 1.5% & 2%) respectively when compared to CC (Control specimen) For M25 grade concrete.

Sakthivel et al.
Experimental investigation on behaviour of HFRC frames with infills against lateral cyclic loads,
Indian journal of engineering, 2013, 5(13), 65-71,

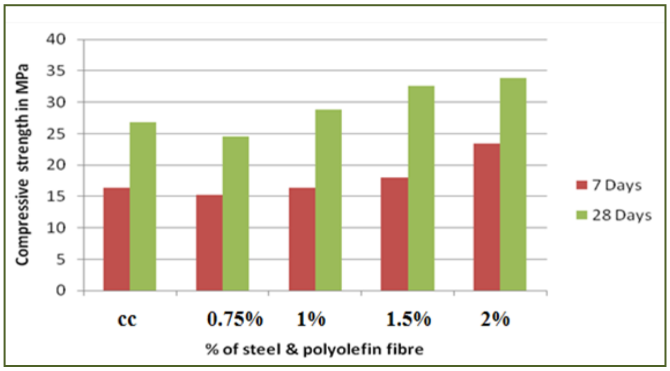


Figure 1
Compressive strength of cube specimens; Note: CC- controlled concrete, HF- hybrid fibers

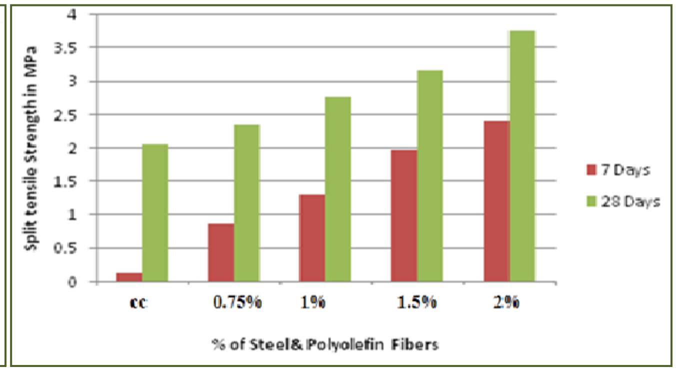


Figure 2
Split tensile strength of cylinders; Note: CC- controlled concrete, HF- hybrid fibers

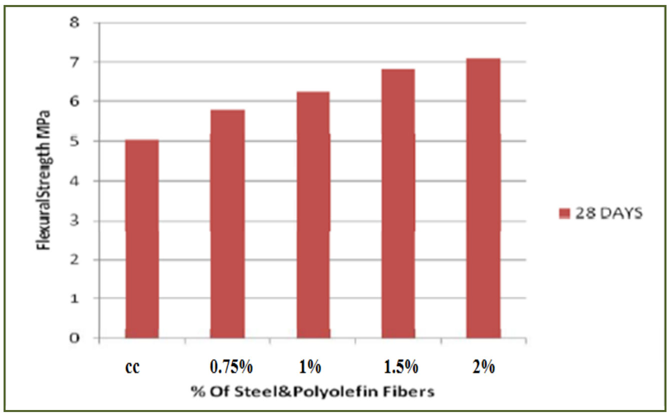


Figure 3
Flexural strength of concrete; Note: CC- controlled concrete, HF- hybrid fibers

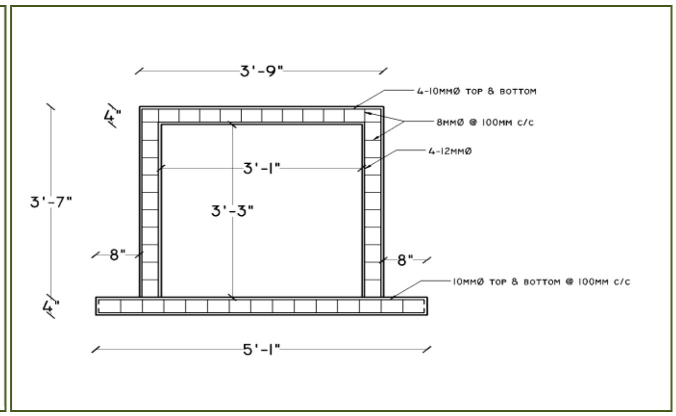


Figure 4
Dimensions of the frame specimen

Figure 5
Lateral load of the frame specimen

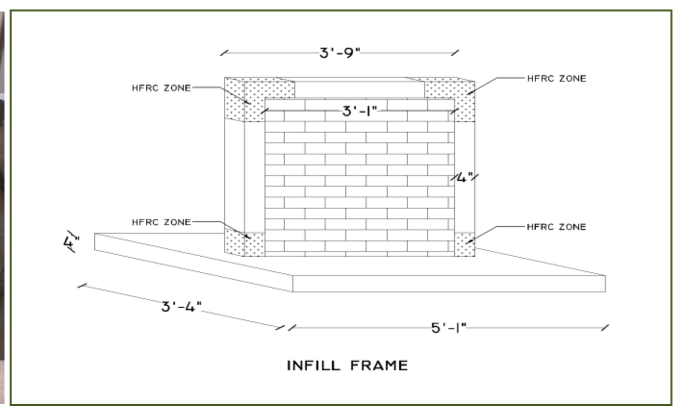


Figure 6.1
Dimensions of the frame specimen

6.2. Split Tensile Strength Test Results

The comparative results for split tensile strength of concrete cylinders between control specimen and HFRC specimens are shown in the graph in Figure 2. The comparison of the 28 days split tensile strength results shows that an increase in split tensile strength for percentage of fibres of (0.75%, 1%, 1.5% & 2%) respectively when compared to CC (Control specimen) for M25 grade concrete.

6.3. Flexural Strength test Results

The comparative results for flexural strength of prism specimen between control specimen and HFRC specimens are shown in the graph in Figure 3. The comparison of the 28 days flexural strength results shows an increase in flexural strength for percentage of fibres of (0.75%, 1%, 1.5% & 2%) respectively when compared to CC (Control specimen) for M25 grade concrete.

Sakthivel et al.
Experimental investigation on behaviour of HFRC frames with infills against lateral cyclic loads,
Indian journal of engineering, 2013, 5(13), 65-71,

Figure 6.2

Frame Model specimen; Complete Setup for the Frame Model

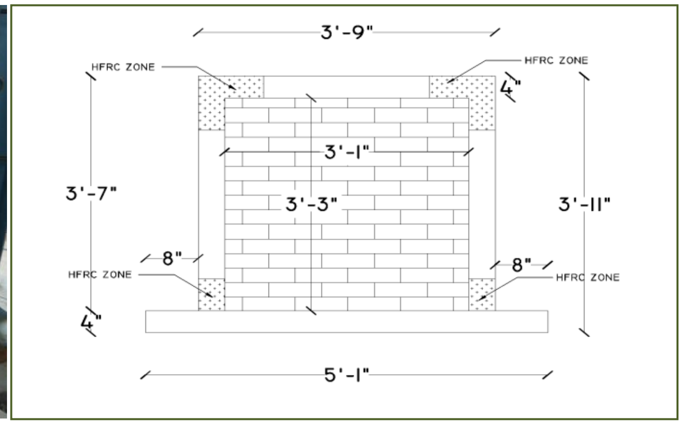


Figure 7

HFRC Zone Area

Figure 8

Casting of frame

Figure 9

Frames under curing

Figure 9.1

Control Specimens of Infill Frames before Testing

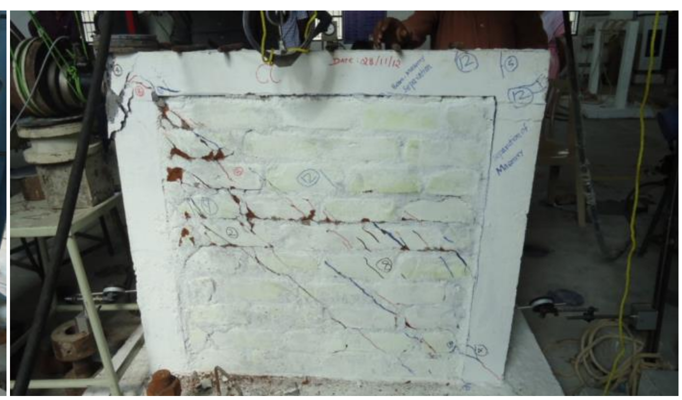


Fig 9.1.1

Control Specimen of Infill Frames after Testing

7. EXPERIMENTAL PROCEDURE FOR HFRC FRAMES

7.1. RC Frames Structure with Infills

- The masonry infill RC frames are the most common type of structures used for multi-storey constructions in the developing countries
- The frames carry gravity loads and earthquake loads while the infills provide a building envelope and or internal partitioning.
- Masonry infills in reinforced concrete buildings cause several undesirable effects under seismic loading: short-column effect, soft-storey effect, torsion, and out-of-plane collapse.
- The masonry infills contribute significant lateral stiffness, strength, overall ductility and energy dissipation capacity (Leon, 1990).

Figure 9.2
0.75% HFRC Infill Frames Before Testing

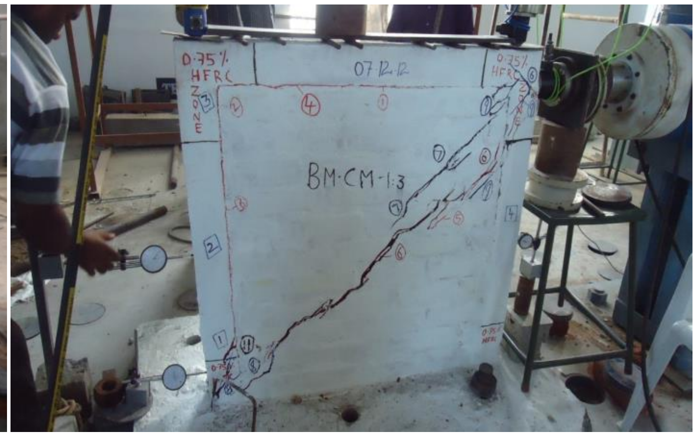


Figure 9.2.1
0.75% HFRC Infill Frames After Testing

Figure 9.3
1.5% HFRC Infill Frames Before Testing

Figure 9.3.1
1.5% HFRC Infill Frames After Testing

Figure 9.4
2.0 % HFRC Infill Frames Before Testing

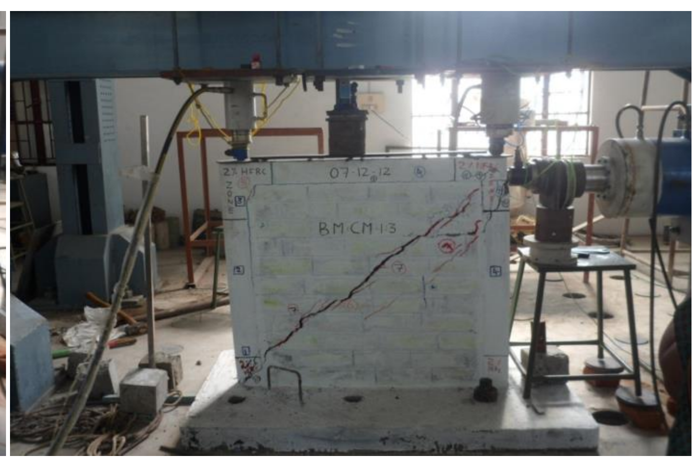


Figure 9.4.1
2.0 % HFRC Infill Frames After Testing

7.2. Details of Frame Specimen

The reinforcement of beam consists of 4numbers of 10mm dia bars top & bottom with a clear cover of 25 mm. The Shear reinforcement includes stirrups of 8mm dia bars at 100mm c/c spacing & the column reinforcement consists 4 numbers of 12 mm dia bar& the slab reinforcement consists 10 mm diameter with 100mm c/c. The dimension of the frame is shown in Figure 4.

7.3. Codal Lateral Load Pattern

Sakthivel et al.
Experimental investigation on behaviour of HFRC frames with infills against lateral cyclic loads,
Indian journal of engineering, 2013, 5(13), 65-71,

Table 3
Experimental results

Frame ID	% of Hybrid Fibre Reinforcement (%)	Experimental Observations	Deflection at Ultimate Load (mm)
		Ultimate Load (kN)	
CC	0	11	11.45
HFRC1	0.75	15	17
HFRC2	1.5	16.7	19
HFRC3	2	24	34

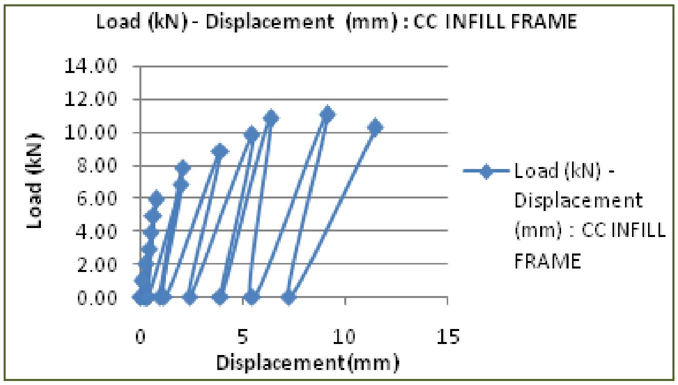


Figure 10.1
Graphical representation of control frame

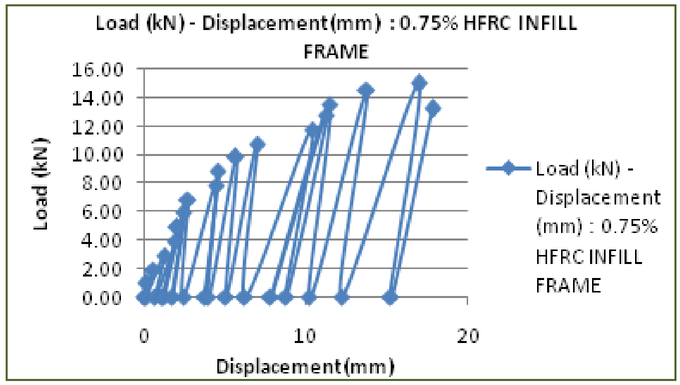


Figure 10.2
Graphical Representation of 0.75% HFRC Frame

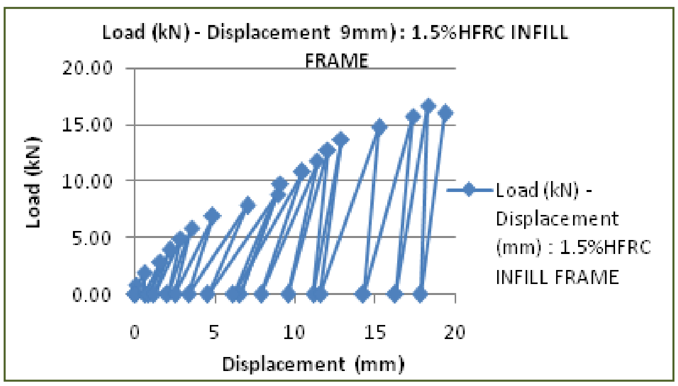


Figure 11.3
Graphical Representation of 1.5% HFRC Frame

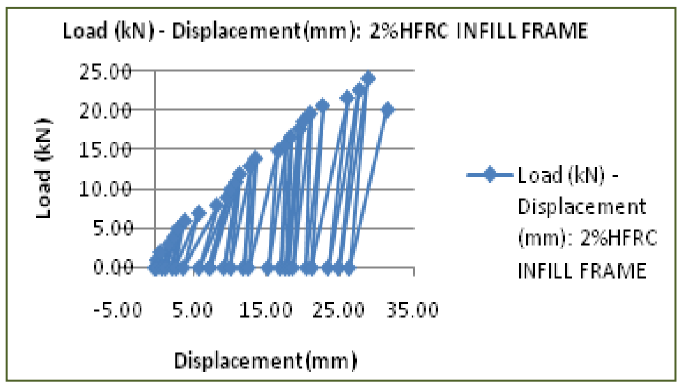


Figure 11.4
Graphical Representation of 2.0% HFRC Frame

This method uses the equivalent lateral forces due to fundamental period of vibrations. The code lateral load shape represents the forces obtained from the predominant mode of the vibration and uses the parabolic distribution of lateral forces along the height of the building. In addition to these lateral loadings the structures are subjected to dead loads and live loads (Figure 5). Figure 6 show the complete test setup adopted for the frame model. The effectiveness of instrumentation set up and the loading were checked in the beginning by loading and unloading the frame with small loads (of the orders of 2.5 KN) till all the readings was repeatable. The frame was subjected to equivalent static lateral cyclic loading. The loading sequences in the beginning were almost same. The load increment for each cycle was 2.50kN at all the stages. The deflections were measured at each increment or decrement of load. The strains in steel, concrete and infill were monitored at maximum load of each cycle and at unloading conditions of frame (i.e. when the load is released fully) during all cycles of loading. The formation and propagation of cracks, hinge formation and failure pattern have been recorded. Before testing, all the frames are marked by points in the outer most column of the portal frame from which the LVDT is placed at 25cm, 50cm & 95cm from the top of the raft slab. LVDT is connected to the transducer to find out the deflection in outer most columns due to lateral load (Figure 7 to 9).

8. EXPERIMENTAL RESULTS (WITH INFILLS)

Experimental results are shown in Table 3.

9. LOAD VS DISPLACEMENT DIAGRAM

- The first crack was witnessed in the interface between brick infill and beam.
- The cracking occurred during loading reflect the fact that the in-filled frame behaved as an integral unit. At failure, the in-filled frame exhibited spalling of brick fragments.
- The formation of plastic hinges in the beam-column joints observed after severe cracking of brickwork.
- The failures occurred in the beam-column joints and in the interface between beam-brick infill. From the above table it is seen that the ultimate load for the HFRC frames is increased when compared to that of the control frame, and the variation in deflection is also large. So it is concluded that the HFRC model performs well when compared to the control specimen (Figure 10).

Sakthivel et al.
Experimental investigation on behaviour of HFRC frames with infills against lateral cyclic loads,
Indian journal of engineering, 2013, 5(13), 65-71,

10. CONCLUSIONS

Based on the experimental results of this thesis, the following conclusions are drawn for HFRC frames with infills subjected to lateral cyclic loading.

- The joint shear stress appears to have a significant effect on strength and stiffness of sub assemblage at lower ductility levels. The shear reinforcement in joint core portion can be increased some more percentage over the requirement as per IS code.
- The load carrying capacity of the in-filled RC frame with hybrid fibre strengthening is more than that of in-filled RC frames without fibre reinforcement.
- Separation of infill occurred at tension corners and crushing occurred at loaded diagonals due to high stress concentration.
- The percentage of fibres used was 1.5% and 2% and the results were found to be increasing.
- Cracks in the in-filled RC were found to be numerous and extensive and in the form of diagonal cracks.
- The contribution of the infills leads to the increase on lateral stiffness of the frame.

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Sakthivel et al.
Experimental investigation on behaviour of HFRC frames with infills against lateral cyclic loads,
Indian journal of engineering, 2013, 5(13), 65-71,